Water

P.E.I.'s MOST PRECIOUS RESOURCE

GROUNDWATER RESOURCES EVALUATION

MIMINEGASH

THE CANADA – PRINCE EDWARD ISLAND
WATER MANAGEMENT AGREEMENT

Environment Canada Environnement Canada

Prince Edward Island
Department of the Environment

GROUNDWATER RESOURCES EVALUATION

MIMINEGASH

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Groundwater Resources Evaluation - Miminegash

Executive Summary

A test drilling and pump testing program as well as a review of the available hydrogeological data for the Miminegash area was conducted during 1989-90 to document the current status of groundwater resources in the community. The results of this investigation indicate that while individual well yields are relatively low, water supplies sufficient capacity to meet normal domestic requirements can be secured, and groundwater quality issues constitute the greatest constraint to water supply development.

Water quality and hydrogeologic data suggest a relatively complex hydrogeologic system exists in the area and groundwater quality is influenced the interaction of shallow local flow systems, a deeper regional flow system and the ocean. Principle water quality concerns are the presence of brackish water near the coast and occasionally elevated iron and manganese concentrations associated with the regional flow system at depth. Water quality form the shallow localized flow systems, although relatively hard, tends to be of the best natural quality, but is also more vulnerable to contamination form surface or near surface sources.

While man-made influences on groundwater quality have had only a limited impact on water supplies thus far, the community can not afford to allow any unnecessary degradation of it's groundwater resources. Public awareness of the importance of proper well construction practices, appropriate septic system design and maintenance and safe handling and storage of hazardous materials including petroleum products will help ensure the preservation of this resource.

Test drilling and pump testing in Miminegash indicates that only modest yields can be expected form individual production wells however two or three wells should be capable of meeting the domestic requirements of the entire community should the development of a central water supply system be desirable or necessary. There are only a limited number of locations within the community where such a supply could be secured and protection of lands suitable for the development a well field will help ensure that the communities' water supply options are left open for the future. It is suggested that the area in which the test drilling was conducted may be as suitable for this purpose as any other area.

Acknowledgments

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MIMINEGASH

1. Introduction

This report documents the findings of a study conducted as part of the Groundwater Resource Evaluation Project under the Canada - P.E.I. Water Management Agreement. These studies are aimed at evaluating the available quantity and quality of groundwater resources in selected communities across the Island.

2. Geography

2.1 Physical Geography

Miminegash is located on the coast, at the western end of Prince Edward Island, 150 Km. from Charlottetown. The topography of the area is dominated by a gentle ridge, with a maximum elevation of 12 m, located along the eastern border of the community, falling away gently to the west and more steeply to the east. To the east this ridge is bounded by lower lying swampy land in the north and further to the south,a small creek which runs to the south west where it empties into Miminegash Pond. The bulk of the community is situated on the western slope of the ridge between Route 14 and the harbour. The ocean, harbour , Miminegash Pond and the creek along the eastern flank of the ridge are the only water bodies of significance in the area. A considerable portion of the community, especially south of the harbour is at elevations of 4 m. or less and appears to be rather poorly drained.

2.2 Cultural Geography

The Community of Miminegash covers an area of approximately 110 hectares. Fishing, the harvesting of Irish moss and farming constitute the main occupations in the community, along with a few smaller retail and service businesses. The population, according to the 1986 census was 288. It is likely that the population of Miminegash will not grow substantially in the near future.

3. Geology

3.1 Surficial Geology

Overburden in the Miminigash area consists primarily of glaciomarine sands, with minor silt and clay (Prest , 1973). The flat foreshore around the harbour is composed primarily of sand dune deposits. The remainder of the area, on the eastern side of the community, is underlain by clay and clay - silt phase till deposited as ground moraine. From previous information (Pollitt 1951) and the stratigraphic logs on the well drillers reports, overburden thickness averages 6.0 m.

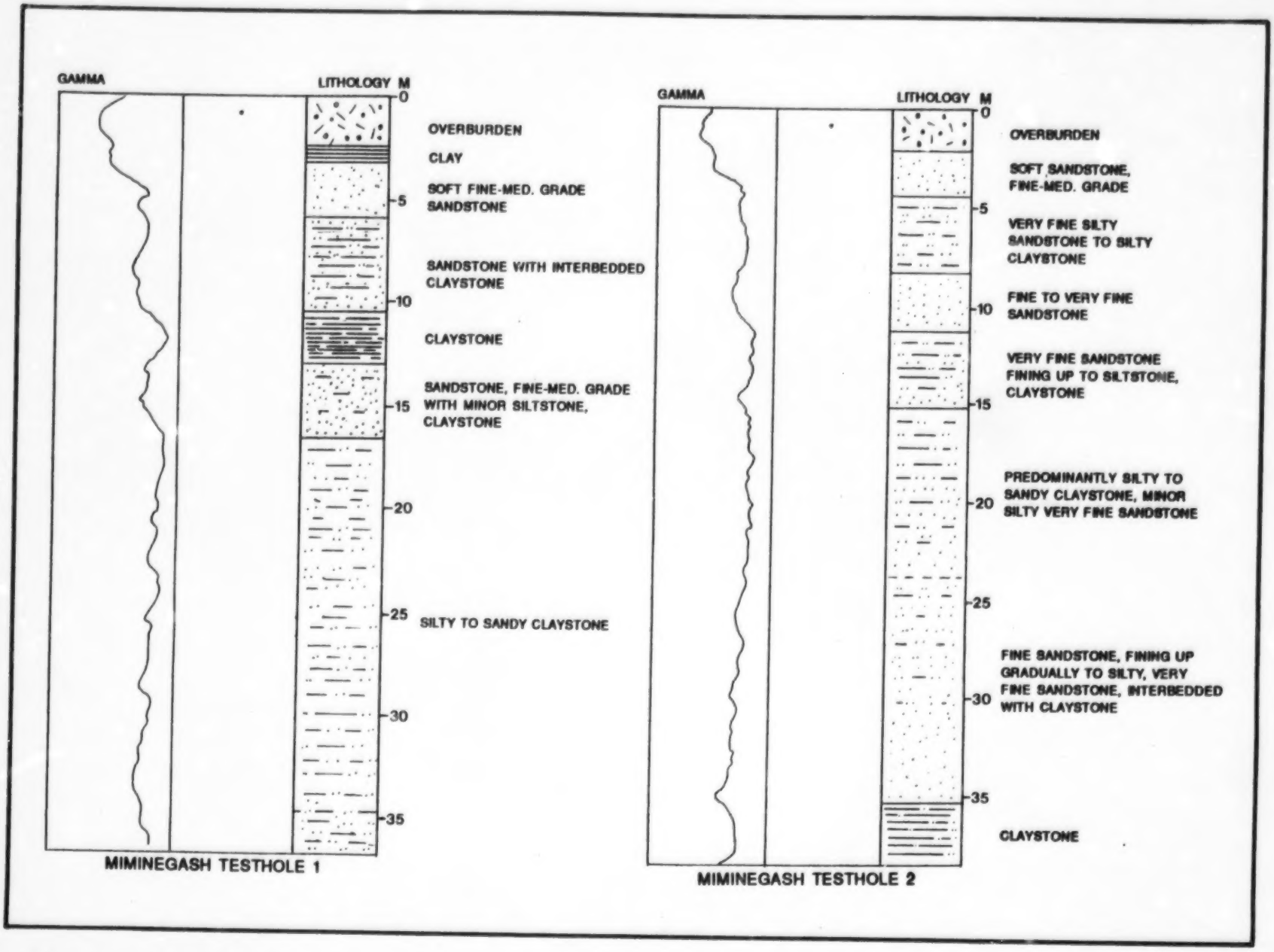
The soil survey report (MacDougal &Veer, 1981) indicates soils in this area fall into 2 main categories. The ridge is covered by Haliburton series soils, which is described as a moderately coarse textured, acid, non-compact glacial till on undulating topography , with good surface drainage, and good to moderate subsoil permeability (greater than 1 x 10-4 cm/sec), and deep water tables . The western slopes are composed of a variety of glaciomarine deposits (40% Rocky Point series, 20% West Point Series and 10% Munn Road Series) which are generally coarse to medium textured soils, on level to gently undulating relief. These soils typically have imperfect to very poor surface drainage, and high water tables.

3.2 Bedrock Geology

Bedrock consists of Upper Pennsylvanian to Lower Permian sedimentary strata of megacyclic sequence I (van de Poll 1981). Miminegash is located on the boundary between Megacyclic Sequence I which consists of red and gray sandstone and siltstone with minor conglomerate, and Subcyclic Sequence IA which consists of red, coarse to fine grained sandstone and siltstone. These strata are believed to be slightly younger equivalents of the Pictou Group of sediments found throughout the Maritime provinces. The environment of deposition of these sediments is believed to be fluvial in origin, and the stratigraphy is characterized by rapid lateral facies changes, representing recurring fluvial cycles.

Well drillers reports and two test holes drilled in the community indicate that siltstone and claystone make up a high proportion of the bedrock at least at shallow depths. Lithological and gamma logs of two test holes drilled during this investigation are shown on Figure 1.

Figure 1


GAMMA
LITHOLOGY
M
0
5
10
15
20
25
30
35
OVERBURDEN
CLAY
SOFT FINE-MED. GRADE SANDSTONE
SANDSTONE WITH INTERBEDDED CLAYSTONE
CLAYSTONE
SANDSTONE, FINE-MED. GRADE WITH MINOR SILTSTONE, CLAYSTONE
SILTY TO SANDY CLAYSTONE
MIMINEGASH TESTHOLE 1
GAMMA
LITHOLOGY
M
0
5
10
15
20
25
30
35
OVERBURDEN
SOFT SANDSTONE, FINE-MED. GRADE
VERY FINE SILTY SANDSTONE TO SILTY CLAYSTONE
FINE TO VERY FINE SANDSTONE
VERY FINE SANDSTONE FINING UP TO SILTSTONE, CLAYSTONE
PREDOMINANTLY SILTY TO SANDY CLAYSTONE, MINOR SILTY VERY FINE SANDSTONE
FINE SANDSTONE, FINING UP GRADUALLY TO SILTY, VERY FINE SANDSTONE, INTERBEDDED WITH CLAYSTONE
CLAYSTONE
MIMINEGASH TESTHOLE 2

4. Hydrogeology

4.1 Existing Well Data

The P.E.I. Department of the Environment has approximately 50 well drillers reports for wells drilled in the Miminegash area since 1970. Well depths in the community average 27 m in depth, and show a considerable range of depths from as shallow as 12 m to as deep as 61 m. Nearly one third of the wells are 18 m or less in depth. The shallow depth of these wells is due in large part to efforts to avoid saline water which occurs at depth through much of the area, and to tap shallower, fresh water bearing portions of the aquifer.

Casing lengths in the wells average 12 m in length and range from as little as 3.5 m to a maximum of 21 m. Again the desire to tap shallow portions of the aquifer has probably influenced the amount of casing used in construction of these wells.

Static water levels in the community, as reported on well drillers reports, average 7.3 m, with a reported range of 1.5 to 17 m below ground level. Considering the fact that the maximum ground elevation in the community is only in the range of 11 or 12 m above sea level, this data must be somewhat suspect, as any static water levels below 12 m would indicate a piezometric surface below sea level. Since the coastline effectively represents a constant head boundary it is more likely that many of these water level measurements have been made shortly after completion of the well, before water levels have completely recovered from bailing or yield testing. From this perspective, static water levels could be viewed as a minimum or conservative estimate of pieziometric head (ie. true static water levels will be at least as high, or higher than the values reported).

Average well yields in the community average 0.38 litres per second (L/sec.) ranging from as low as 0.15 L/sec. to as high as 1.5 L/sec. While the yield tests on which these values are based are generally only short duration (15 minute) bail tests, the data probably does reflect generally lower well yields in this area relative to many other parts of the Island.

To make the well yield data more meaningful the well yield data from the well drillers reports, the well depth, or more precisely the saturated thickness of the aquifer penetrated by individual wells must be taken into account. All other factors being equal, a deeper well with a greater depth of open hole below the water table would be expected to yield a greater quantity of water than a shallower well. To evaluate the water yielding characteristics of various wells then, it is useful to the into account the saturated thickness (water bearing portion) of each well when considering well yield.

As is common on P.E.I., individual aquifers are difficult to identify, especially as flow of water through fractures is probably more significant that primary porosity in determining hydraulic conductivity. For these reasons the entire saturated thickness of sediments penetrated by the well can be approximated as a single semi-confined aquifer.

As a measure of well yield then, the yield per metre of saturated thickness penetrated, for each well has been calculated. The average yield per metre of saturated thickness (in L/sec./m) is 0.042 ranging from 0.075 L/sec./m to 0.164 L/sec./m This would mean that on average a well 30 m deep with a static water level of 12 m, would be expected to yield approximately 0.75 L/sec.

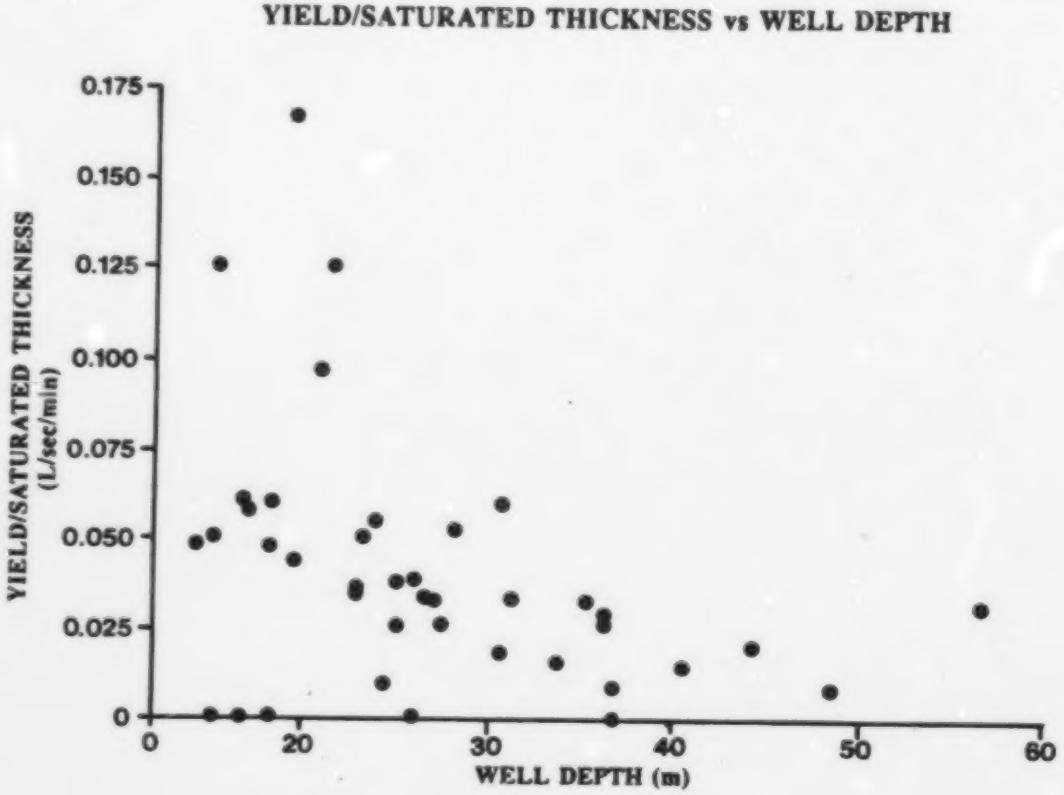
Two test holes drilled as part of this study confirm the relatively low well yields in the Miminegash area with yields of 1.14 and 1.89 L/sec. respectively. The yield per foot of saturated aquifer thickness for these same test holes is approximately 0.04 and 0.07 L/sec./m

To a significant extent, the lower well yields in this area are likely to be a reflection of the underlying bedrock conditions in this region, in particular the high proportion of claystone and siltstone over sandstone in the stratigraphy. Generally the dominating influence on the flow of groundwater on P.E.I. is the distribution of fractures through which water flows rather than inter granular flow. The more plastic nature of claystone, and to some extent siltstone would be expected to limit fracture propagation. Thus it would be likely that both intergranular flow and fracture flow through the underlying aquifer is quite modest when compared to other areas where the stratigraphy is dominated by more massive sandstone sequences.

Figure 2 shows the yield/saturated thickness plotted against well depth for wells in the Miminegash area. While there is a considerable degree of scatter in the data, it is apparent that the yield /saturated thickness (not total well yield) generally declines with increasing well depth.

In many parts of P.E.I. there is also a correlation between static water level and well yield, with wells drilled in areas with high static water levels generally having higher yields. This is attributed to the fact that in areas with high water tables, there is a greater portion of the shallow, highly fractured aquifer that is saturated. These fractures are the dominant source of permeability in the aquifer, and thus wells tapping this shallow zone of fracturing generally can be expected to have higher yields. Because of the suspect nature of many of the static water levels recorded for wells in this area, a similar correlation was not attempted. It is likely however that the same principles would apply in the Miminegash area, low lying areas, where the static water level would be expected to be rather high, would be expected to be good groundwater exploration targets, providing that water quality concerns do not rule out such a location.

Figure 2


YIELD/SATURATED THICKNESS vs WELL DEPTH
YIELD/SATURATED THICKNESS (L/sec/min)
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0
0
20
30
40
50
60
WELL DEPTH (m)

4.2 Test Drilling and Pump Testing

To gain greater insight into aquifer conditions and water quality in the Miminegash area, a test drilling and pump testing program was carried out. This program involved the construction of two test holes and their subsequent pump testing, geophysical logging and water sampling.

4.2.1 Site selection

Three criteria were used in the selection of the test drilling sites (shown on Figure 3), water quality constraints, well yield expectations and groundwater protection considerations. The final decision on site selection was based primarily on a water quality and groundwater protection basis.

Because of the high incidence of saltwater intrusion in the area, as well as the expected occurrence of high iron and manganese concentrations at other locations, a site was sought which would be a sufficient distance from the shore, and on higher ground where groundwater flow might be somewhat more vigorous than low-lying swampy areas.

The existing well data, as well as morphological conditions did not point to any particular areas where higher than average well yields might be found. Additionally, because of the relatively small population of the community, it was not felt that particularly large well yields would be a priority, at least when weighed against water quality constraints. The one well in the community with higher than average well yield is located at the Fire Hall, although a petroleum spill in the area made this immediate location undesirable.

Finally it was desired to conduct the test drilling and pump testing in a location in which reasonable measures to protect the wells from groundwater contamination could be implemented. Towards this purpose a site was chosen in which little development has occurred. The site chosen is situated adjacent to agricultural land which for the most part is compatible with the development of a water supply.

Because of weather conditions, access at the test drilling site was somewhat limited. Initial intentions were to site the wells at a location further back from the road. It is felt however that because of the modest water withdrawals expected from these wells, that the sites chosen would not create an undo risk of contamination. Nonetheless, if further development of a water supply was to take place at some time in the future, consideration should be given to locating any future wells further to the east, away from the road. The location of the test wells is indicated on Figure 3.

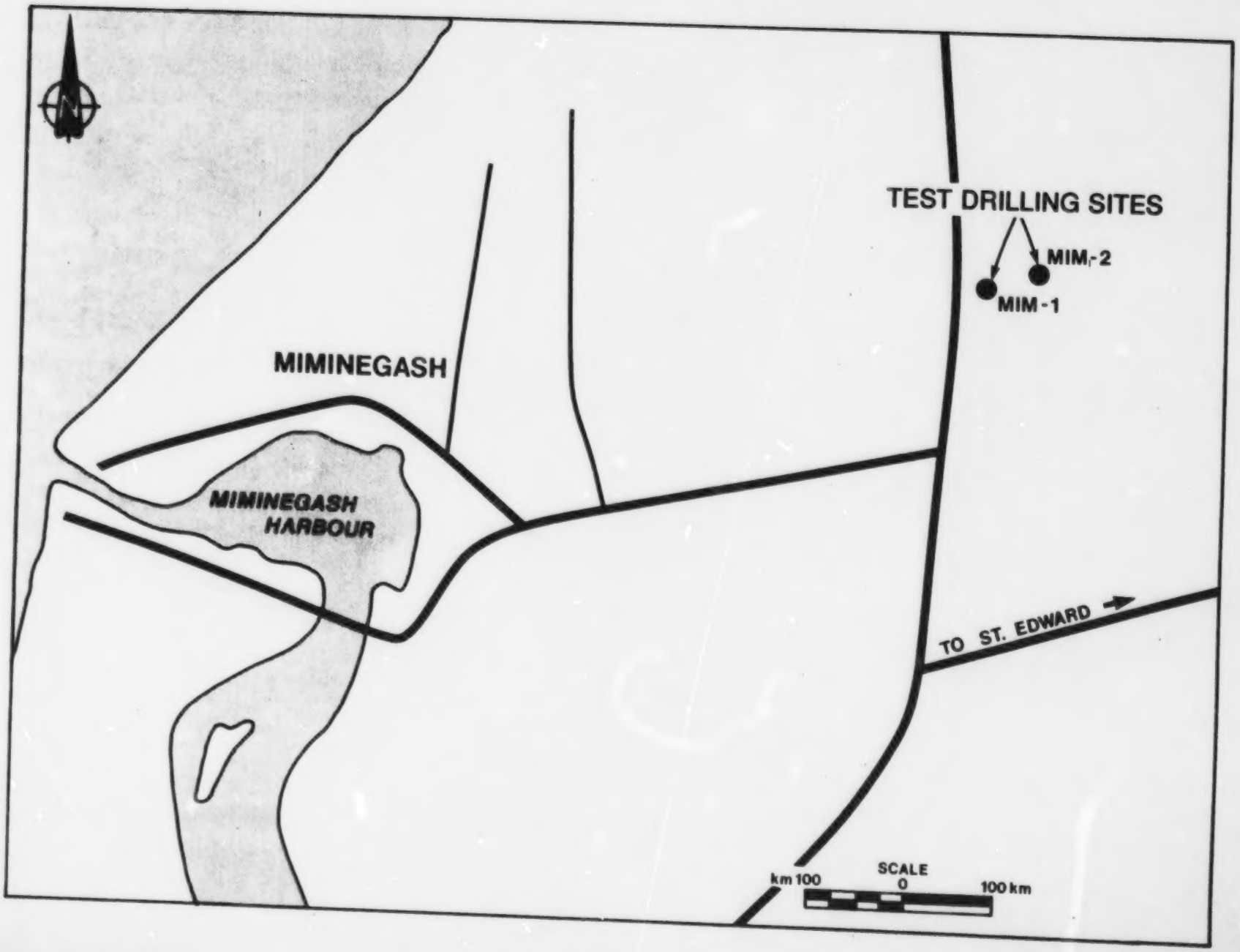

TEST DRILLING SITES
MIM-2
MIM-1
MIMINEGASH
MIMINEGASH HARBOUR
TO ST. EDWARD
km 100
SCALE
0
100 km

Figure 3

4.2.2 Test Drilling

Two test wells were constructed approximately 45 m apart to a depth of 45 m. Well depth was limited to this depth to minimize the likelihood of encountering saline ground water. Both wells are 15 cm in diameter and cased to a depth of 12 m. Two 22 Kg bags of granular bentonite were used to seal the lower portion of the annular space between the casing and the well bore in each well, to prevent the vertical migration of water form the surface or near surface into the well. Static water levels in the two wells at completion of drilling were 11.5 m and 11.7 m respectively for test hole MIM-1 and MIM-2.

During drilling, samples of drill cuttings were collected at 3 m intervals and logged. Subseqent to drilling and pump testing, each well was logged with a gamma tool, flowmeter and conductivity probe. The lithological and gamma log for each well was presented on Figure 1.

4.2.3 Pump Testing

Following completion of test drilling each well was subjected to a step drawdown pump test to determine well performance, and to select the most appropriate pumping rate for a constant rate test. Subsequently a 48 hour constant rate test was conducted to assess aquifer characteristics at the site.

Step drawdown tests:

For test hole MIM-1 three pumping steps were attempted at rates of 0.75, 1.5, and 2.3 litres per second (L/sec.). A 3 H.P. submersible pump was set at a depth of 37 m and water levels were measured through a drop pipe with an electric water level tape. Pump discharge was measured using a 22 litre container and a stop watch.

During the test it was found that a pumping rate of 1.5 L/sec. could only be maintained for a few minutes and the test was aborted at this stage. Based on the single 0.75 L/sec. stage the specific capacity of this well was approximately 0.06 L/sec./m. (Specific capacity is a measure of well performance and represents the amount of drawdown in a well for a given pumping rate over a fixed period of time). The value of only 0.06 L/sec./m is relatively low and represents relatively poor well performance, when compared to wells of similar construction in many other parts of the Island.

Test well MIM-2 was subjected to a similar step drawdown test, proceeding to successively higher pumping rates at intervals of 0.75 L/sec. The well could maintain a flow of 2.3 L/sec. for the thirty minute step, but could not maintain a discharge of 3.0 L/sec. for more than a few minutes before the water level approached the level of the pump inlet. Table 1 shows the pumping rates, water levels and specific capacities for this test.

Table 1 Step Drawdown Test Data, Test Well MIM-2

step	Q L/sec	W.L. (m)	D.D. (m)	S.C. (L/sec./m)
1	0.75	14.96	3.04	0.25
2	1.5	24.54	12.55	0.12
3	2.3	32.25	20.12	0.11

Note: Q = discharge rate, W.L. = pumping water level, D.D. = drawdown, S.C. = specific capacity

It will be noted that the specific capacity for the well declines with increasing pumping rate. This is a common phenomena, and reflects the impact of increasing head losses (well losses), due probably to increasing component of turbulent flow in and around the well bore. It is interesting the larger drop in specific capacity occurs between the lowest and intermediate pumping rate. This may indicate that much of the water in the well is being contributed from fairly shallow fractures which have become drained as the water level in the well declines.

It should be noted however, that this data is based on only short duration pumping stages (1/2 hour) and that the actual drawdown over longer periods would be expected to be somewhat greater. In addition caution should be exercised in extrapolating beyond the maximum pumping rate at which the testing was conducted, as the relationship upon which predictions are based is only approximate. It is possible that drawdown could increase quite substantially at pumping rates only slightly above the maximum rate at which the well was tested. It is will be recalled that the well failed to maintain a flow of 3 L/sec. for more than a few minutes.

Based on the step drawdown data, it is probable that the maximum "safe" or "sustainable" yield from test hole MIM-1 is in the range of 0.75 to 1.1 L/sec. For test hole MIM-2 the rate would be somewhat higher, perhaps in the range of 1.5 to 1.9 L/sec. Although the well was successfully pumped for thirty minutes at a rate of 2.3 L/sec. it is uncertain if this rate could be sustained indefinitely, at least with a pump setting of 37 m.

Constant rate test:

Based on the step drawdown test data it was decided that test well MIM-2 would be pumped at a rate of 1.5 L/sec. for a period of 48 hours to further assess the aquifer characteristics at the site. Drawdown measurements were recorded in both the pumping well and in test hole MIM-1 which was used as an observation well during the test. Following the 48 hour pumping period, recovery measurements were made in the pumping well, with a few measurements being recorded from the observation well.

The data from the constant rate test were analyzed using the Theis curve matching technique, Jacob non - equilibrium formula (straight line method) and from recovery data, to determine aquifer transmissibility and storativity. Transmissibility (T) is a measure of how easily groundwater can move through the ground while the storage coefficient is a measure of the amount of water which is released by the aquifer for a unit decline in water level. Both computer fitted and manual procedures were used in the analysis of the data. The results of these analyses, based on observation well data, indicate an average transmissibility value of 28 m^2/day, and a storativity coefficient of 1.27 x 10-4 , (see Table 2).

As can be seen from Table 2, there is relatively good agreement between the values for T and S for all the analyses of data from the observation well. There is considerable amount of variation in values computed from pumping well data. The lower T value (relative to those calculated from the observation well data) indicated by the Jacob straight line method for pumping well data can probably be explained by well losses in the pumping well . It is more difficult to explain the low value obtained from analysis of the recovery data, as well losses should be non - existent a short time after pumping has ceased.

Table 2

Method of analysis	T(m^2/day)	Storativity
Observation well data:		
Theis (manual)	27.3	1.02 x 10-4
Thcvfit (computer aided fit)	28.1	1.22 x 10-4
Jacob (manual)	29.2	1.39 x 10-4
Jacobfit (computer fit)	27.4	1.45 x 10-4
Pumping well data:		
Jacob (manual)	15.7	-
Jacob (computer fit)	25.0	-
Recovery data (computer fit)	5.2	-

Given T and S values from the constant rate test it is possible to make an estimate of the efficiency of these wells. Efficiency is meant here as a measure of well performance in which the actual drawdown of water level during pumping is compared to a theoretical value calculated based on the aquifer parameters derived from the pump testing. The differences between these two values can generally be attributed to the well losses referred to above in the discussion of the step drawdown test data.

Based on a transmissibility value of 28 m^2/day, a storativity coefficient of 1.27 x 10-4, and a pumping rate of 1.5 L/sec. for a period of 48 hours, the predicted pumping water level in the test well MIM-2 is in the range of 6.7 m. Actual drawdown in the pumping well at the end of the 48 hour constant rate test was over twice this amount at 15 m feet. Thus it can be concluded that the well has an efficiency of approximately 45%, or in other words just over half of the drawdown in the pumping well was a result of head loss in and around the well bore, not an overall lowering of the water table. A similar calculation for test hole MIM-1, albeit based on a shorter period of pumping but using the same aquifer parameters and a pumping rate of .75 L/sec., indicates an efficiency of only 21%.

4.3 Groundwater Flow Regime

With the available data, it is difficult to define in detail, the hydrogeological regime in the region. However the well drillers reports, the test drilling program, and the available water quality analysis, do provided some insight into the factors that influence the groundwater flow regime in the Miminegash area.

In general, the configuration of a groundwater flow system is determined by the hydraulic conductivity of the aquifer(s), the hydraulic gradients throughout the system and the nature of the boundaries of the flow system. These factors in turn are influenced by such factors as topography, the nature of the aquifer materials, the rate of groundwater recharge and the proximity to large scale geographical features such as the ocean.

Some of the main features which play a role in determining the nature and occurrence of groundwater in the Miminegash area are the relatively even, low - lying topography, the proximity to the coast and the relatively clay rich nature of the underlying bedrock aquifer.

With the relatively flat topography in this portion of Prince County, hydraulic gradients would be expected to be very low. (the maximum relief in the immediate vicinity of Miminegash is about 12 m). As it is the hydraulic gradient that is the "driving force" behind the movement of groundwater, groundwater flow in the area is expected to be relatively slow.

In addition, it is the topography which generally determines the boundaries of flow systems on the Island. In the Miminegash area, where topography is characterized by relatively low, gentle rises and shallow depressions, superimposed on a gently sloping lowland area, local flow systems are likely to be of limited extent, with larger regional flow systems dominating the hydrogeological regime at depth.

Bedrock across the Island is generally composed of interbedded sequences of sandstone, siltstone and claystone and/or mudstone. In the Miminegash area the less permeable claystones make up a higher proportion of the bedrock than is typical in many other parts of the Island. This feature is likely to contribute further to the slow movement of groundwater in the area.

The close proximity to the shore also plays a major role in the hydrogeologic regime in the area. The shoreline outlines a constant head boundary and delineates the seaward extent of the fresh water flow regime. In addition this interface is generally inclined in an inland direction, thus the position and nature of this interface plays an important role in determining the chemical characteristics of water in the near shore environment.

Taken together, these factors determine the gross characteristics of groundwater flow and water chemistry in the region. Taking a rather simplistic view, it appears that two different types of flow systems influence the area; relatively shallow localized systems, and a deeper, more extensive regional flow system. While in reality there is probably no sharp dividing line between these systems, it is convenient here to treat them as two distinct entities as a first approximation. Two separate lines of evidence support the existence of these two systems; static water level data and water chemistry data.

First, a review of data from the well drillers reports and the test drilling program show that virtually all of the deeper wells in the area, regardless of location, have static water levels at or just above sea level, while shallower wells and reports of water occurrences indicate static water levels somewhat above sea level at shallower depths.

It may be noted that much of the static water level data from well drillers reports may be somewhat suspect because many of the measurements may have been taken before the wells have had an opportunity to completely recover from bailing or testing. However, data from the two test wells, which are located a considerable distance from the coast, and near the maximum elevation in the community, confirms a static water level at or just slightly above sea level in deeper wells in the Miminegash area. At the same time water occurrences encountered during drilling indicates the presence of water bearing horizons at depths as shallow as 4.6 m below ground surface (approximately 5.5 m above sea level).

While this alone may prove little more than the fact that most of the area is a recharge area, when correlated with water chemistry data the case for two distinct groundwater flow regimes becomes stronger.

Water chemistry data from wells in the study area exhibit quite a range of compositions (see the Piper diagram in Figure 4 and the discussion of baseline water quality in section 5). Furthermore these different water "types" can at least crudely be correlated with different hydrogeological environments.

Water from shallow wells, generally has high hardness, low chlorides and compositions dominated by calcium and bicarbonate and is denoted as region "A" on the piper diagram on Figure 4 . This composition is typical of much of the groundwater found on the Island and may be taken to represent, in relative terms, rather young or juvenile water which has had only a modest contact time with the aquifer materials. The dominant ions calcium and bicarbonate probably result from the dissolution of the calcium carbonate cement.

Typically wells which penetrate deeper in the ground, yield water which is very soft, although the water is high in alkalinity (bicarbonate) and sodium. This water "type" is denoted on the Piper diagram as region "B". This water composition is not uncommon in the Miminegash area, as well as a few other areas in the province. It represents older water which has had prolonged contact with the aquifer materials.

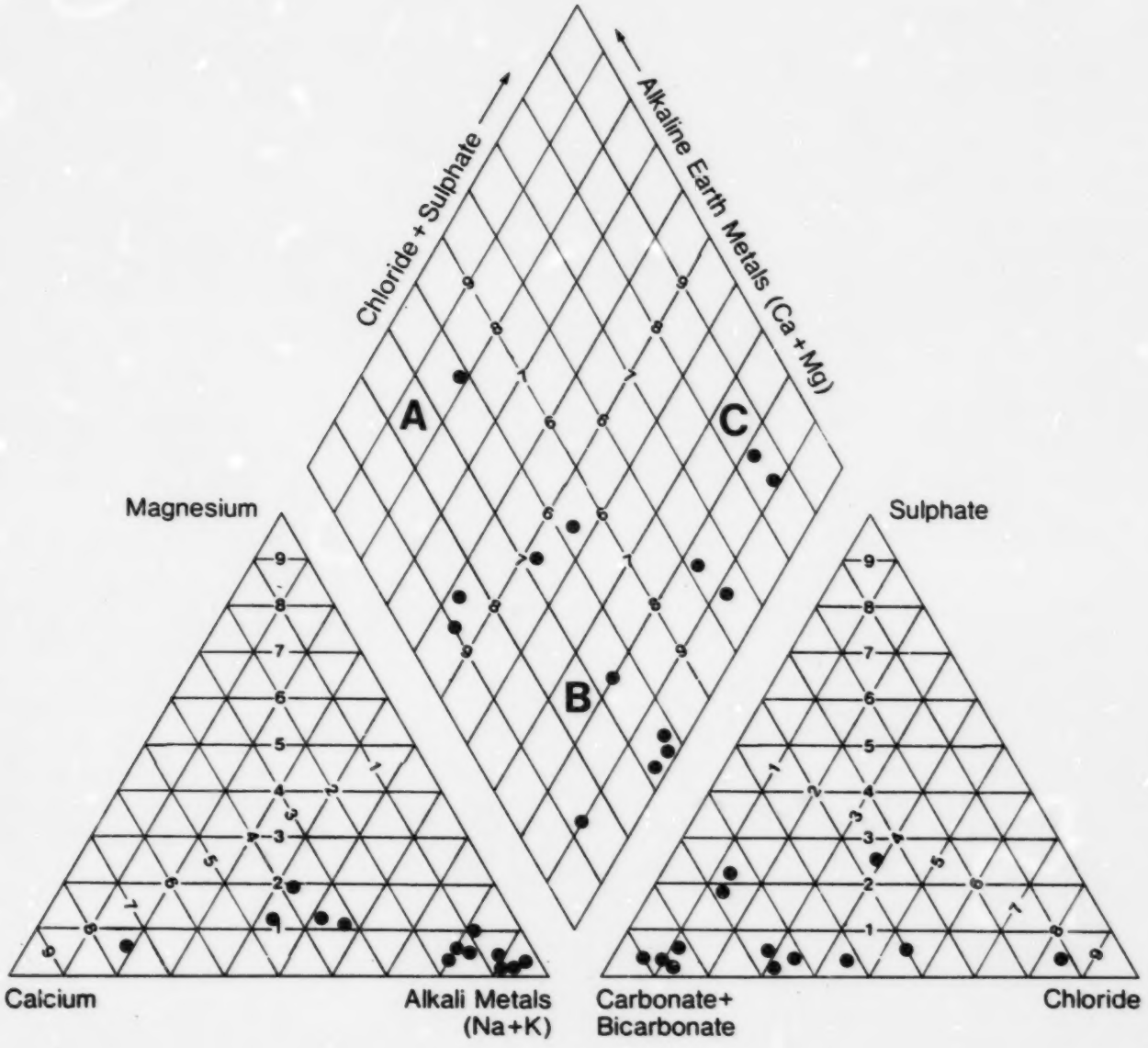
This water chemistry is believed to be the result of a natural water softening process where by calcium ions found in younger waters is progressively exchanged for sodium ions on clay minerals in the aquifer through time. Thus this older water which has had had a prolonged contact time with clay rich sediments becomes progressively richer in sodium and poorer in calcium through time.

It is worth noting in conducting conductivity profiles of the two test holes both showed an increase in conductivity with depth, particularly in the bottom of test hole MIM-2. A review of the chemistry of water samples from the wells indicates that this elevated conductivity is a result of high sodium and bicarbonate ions, which would be associated with this natural softening effect, and not with elevated chloride levels associated with salt water intrusion.

Finally, the influence of sea water dominates water quality in portions of the Miminegash area. Sea water has a high concentration of sodium and chloride ions and is low (relatively speaking) in calcium and bicarbonate (shown as region "C" on the Piper diagram).

The subsurface interface between groundwater derived from sea water and fresh groundwater is generally described as a sloping plane that dips inland at an angle (see Figure 5), so that in areas near the shore, fresh water will be encountered at shallow depths and salty water at greater depths. The depth to the salty water depends, among other factors, on the fresh water head (elevation of the water table) at that location. Generally speaking the higher the water table, the deeper the saltwater fresh water interface will be.

Figure 4


Chloride + Sulphate
Alkaline Earth Metals (Ca + Mg)
A
B
C
Magnesium
Sulphate
Calcium
Alkali Metals
(Na+K)
Carbonate+
Bicarbonate
Chloride

Only rarely in nature this dividing line between salt and fresh water sharp; rather a "zone of diffusion" exists in which there is a transition between sea water compositions and fresh water compositions. Where this mixing takes place, compositions with high sodium and chlorides results. The concentrations of sodium and chloride observed depend on the degree of mixing of the two water types. Below this zone, compositions more similar to sea water are generally found.

Within the lower lying, western portion of the Miminegash area, "sodium chloride waters", typical of the "zone of diffusion" are commonly encountered at relatively shallow depths, making it difficult to obtain potable water supplies. It is noteworthy however, that fresh water is occasionally found at depth in this area, where shallower wells have produced brackish water. This suggests that the zone of diffusion is fairly broad, and quite in-homogenous. This may result partly from the strong horizontal anisotropy of the aquifer, with individual zones of higher permeability having distinct head distributions, and freshwater/ saltwater interfaces.

From these rather indirect lines of evidence a rather tentative picture of the groundwater flow regime can be pieced together. Figure 5 is an attempt to show graphically these influences on groundwater flow and chemistry. It should be noted of course, that this picture does not represent a quantitative treatment of the issue; rather it is offered as a conceptual model which may explain some of the observed characteristics of the groundwater flow regime in the area.

In the model, three distinct regions can be identified as follows:

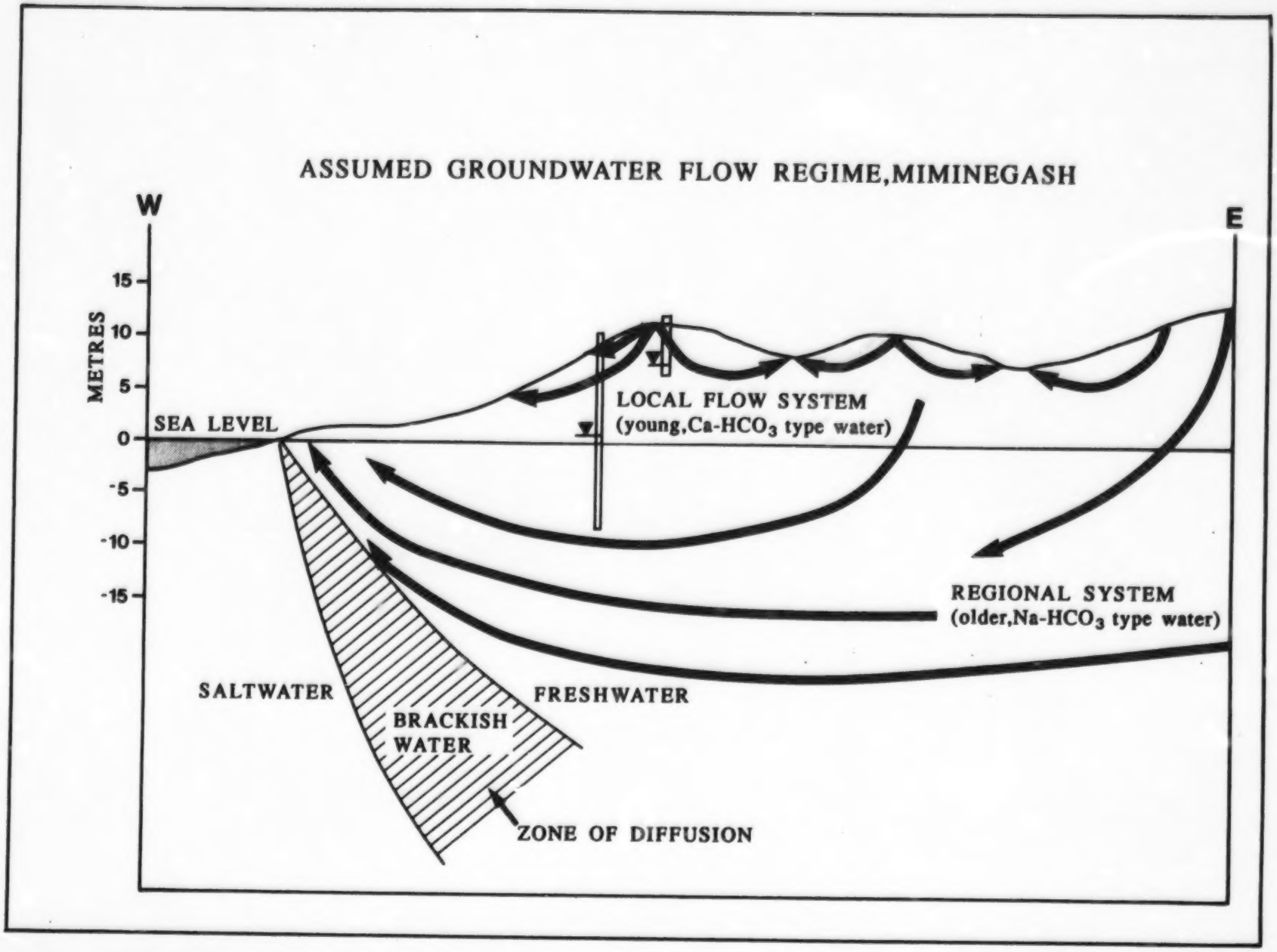
A Shallow, localized flow systems -

These systems are probably defined by local topography with recharge occurring rather directly to the aquifer on areas of higher ground, and discharge occurring in low-lying areas occupied by swamps, streams or near the shore. Flow paths are presumed to be short and with low gradients but with greater aquifer permeabilities at shallow levels, and residence times are likely to be fairly short. The resulting water chemistry is represented by field "A" on the Piper diagram, and is typically hard, and dominated by calcium and bicarbonate ions.

B Deep regional flow system -

This system is probably of wide extent, bounded inland by a larger scale topographic divide at least some miles from the coast. The flow paths for this system are assumed to be quite long and groundwater movement is expected to be very sluggish under a very low hydraulic gradient, and low aquifer permeabilities at depth. A significant portion of recharge probably occurs a considerable distance inland and discharge is likely to be primarily at the coast at the

Figure 5


ASSUMED GROUNDWATER FLOW REGIME, MIMINEGASH
W
E
METRES
15
10
5
0
-5
-10
-15
SEA LEVEL
LOCAL FLOW SYSTEM
(young, Ca-HCO3 type water)
REGIONAL SYSTEM
(older, Na-HCO3 type water)
SALTWATER
FRESHWATER
BRACKISH WATER
ZONE OF DIFFUSION

saltwater/freshwater interface. Consequently residence time is long and the resulting water chemistry shows varying degrees of natural softening due to prolonged contact with clay rich aquifer materials.

The data presented on the Piper diagram suggests a weak trend of values from the more "juvenile" type "A" waters towards the softer waters represented in the "B" region of the graph. This could be interpreted either as a mixing of older naturally softened water and more juvenile waters, or a progressive evolution of juvenile waters toward the older softened water.

C Zone of salt water intrusion -

This zone represents the area where saline sea water and fresh ground water mix in the zone of diffusion. The available chemical analyses suggest that it is predominantly the water from the deeper, regional flow system which is mixing with sea water in the zone of diffusion. If fresh-water from shallower, localized flow systems is mixing with sea water, it may occur in areas or at depths not tapped by a significant number of wells.

As noted above the picture drawn above is highly idealized, however it does provide a framework for understanding some of the observed features of groundwater in the Miminegash region. Some of the implications of this analysis area as follows:

Shallow wells drilled away from the shore should be expected to yield hard water, with low sodium and chloride concentrations, if they are sufficiently far from the shore. The limiting factors for these wells is likely to be low well yields due to the generally high proportion of claystone and low water table elevations, and their relative vulnerability to contamination by surface and near surface water which often plagues shallower wells.

Deeper wells can be expected to produce naturally softened water which is high in sodium. In areas closer to the coast, saltwater intrusion is likely to result in not only high sodium concentrations but high chlorides and higher hardnesses.

Well yields would be expected to be greater only to the extent that a larger portion of the aquifer is tapped by the well, although the deeper portions of the aquifer are likely to have even lower permeabilities than at shallow depths. The greater well depths would provide some additional reservoir or storage in the well.

Groundwater flow is expected to be primarily towards the coast throughout the study area, except perhaps in a few areas of higher ground where shallow flow systems may discharge at lower elevations to the east of the community. Overall groundwater flow is expected to be rather slow in the area.

5.0 Water Quality

5.1 Baseline water quality

Some aspects of water quality in the Miminegash area have been discussed in a fair degree of detail in the preceding section on the groundwater flow regime. As noted in that discussion two different fresh water "types" can be identified, a hard, calcium carbonate water, and a naturally softened sodium carbonate water. In addition to these, water showing characteristics transitional between these types can be found (see trend 1 on the piper diagram on Figure 4) as well as water which shows the influence of saltwater intrusion through high sodium and chloride concentrations (trend 2 on the same plot). Chloride concentrations are generally within the Guidelines for Canadian Drinking Water Quality (Health and Welfare Canada, 1989) except in areas closer the the shore. Nonetheless the presence of salty or brackish groundwater is probably one of the greatest constraints on the development of acceptable water supplies in the area.

In addition to problems of high chloride contents, data from analyses of groundwater in the Miminegash area frequently exhibit high concentrations of manganese and to a lesser extent iron. These occurrences are most likely attributable to the relatively slow movement of groundwater in the area, and a relatively reducing chemical environment. It should be noted that most of the higher iron concentration noted in the data is total iron, and dissolved iron concentrations are generally low (below detection limit). This suggests that most of this iron is being carried by particulate matter (clays and silt) and may be a result of high suspended solids in the water. Neither the high iron or manganese concentrations in the water pose any threats to health, and constitute aesthetic concerns only.

5.2 History of water quality problems

As noted above high chloride, iron and manganese concentrations are among the most commonly reported water quality problems in the Miminegash area. In addition to these naturally occurring conditions, there has been one reported gasoline spill at the Irving service station which has effected the well at the service station as well as one other domestic well.

Some incidences of bacterial contamination of water have been reported, and are probably due to a combination of factors including relatively shallow well casing, and malfunction of septic systems due to poor drainage conditions associated with the relatively tight overburden materials. The level of bacterial contamination is not surprising in light of these conditions, nor is this problem particularly severe in the Miminegash area, relative to the surrounding region.

5.3 Potential Threats to Groundwater Quality

There are relatively few obvious manmade threats to water quality in the Miminegash area. Besides bacterial contamination, the main areas for concern would be the underground storage tanks located at the service station, Fire Hall and around the harbour, and the old abandoned dump site located north of the Miminegash Harbour Road and west of Route 14. This was a Priority III dump site containing household, machinery and metal wastes.

Although relatively limited in extent, agricultural activities in the area have some potential to impact on water quality, especially with regards to possible groundwater contamination by pesticides, nitrates and bacteria.

6. Planning Considerations

The availability and quality of groundwater has been, and continues to be, a source of concern in the Miminegash area. Unfortunately most of these concerns stem from naturally occurring conditions, which are not easily overcome. Poor water quality is not universal in the Miminegash area but in certain areas of the community, especially those areas closest to the harbour, little can be done to improve natural water quality.

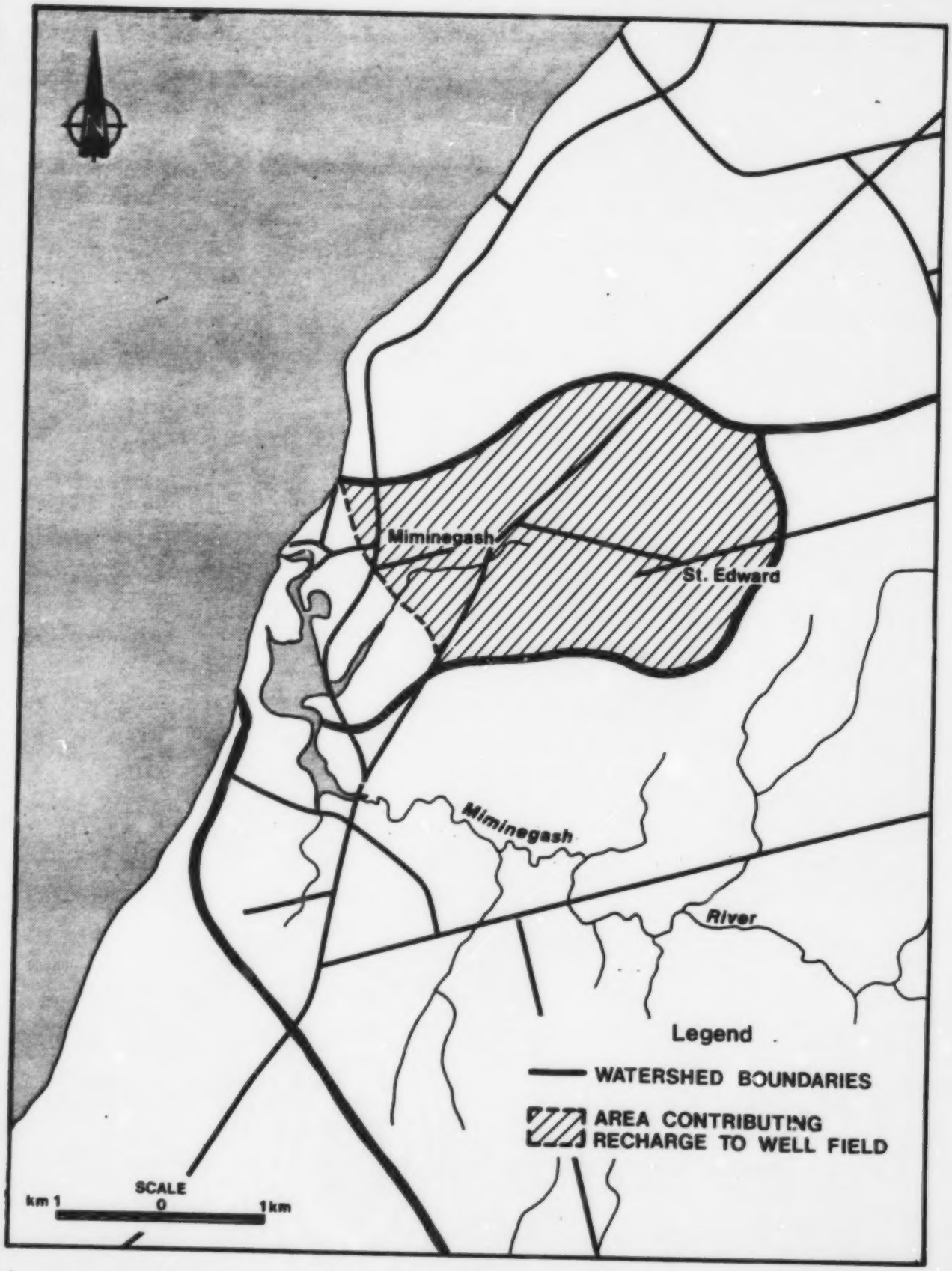
Test drilling and pump testing activities, conducted as part of this study, have identified a limited groundwater resource which could be utilized to meet community needs. The question of whether or not the residents should turn to centralized servicing for part or of their requirements is a complex problem which involves much more than the local hydrogeology. In the sections that follow, the availability of groundwater, in light of the likely community needs are discussed as well as measures which might help protect this resource.

6.1 Availability of Groundwater

A review of existing well data indicates that sufficient water for domestic requirements can usually be obtained from individual on - site water supplies, although in many instances wells may have to be drilled to depths at which salt water intrusion may effect water quality, in order to obtain a well with suitable yield.

Test drilling and pump testing have identified a resource somewhere in the range of 227 m^3/ day to 295 m^3/ day from two test wells. This figure is based on a pumping rate of 0.7 to 1.1 L/sec. from test well MIM-1 and 1.89 to 2.3 L/sec. from test well MIM-2. It should be noted that the only long term testing of these wells was the 48 hour test on test well MIM-2, and thus caution should be exercised when extrapolating some of these values to longer term pumping periods.

Figure 6


Miminegash
St. Edward
Miminegash
River
Legend
WATERSHED BOUNDARIES
AREA CONTRIBUTING
RECHARGE TO WELL FIELD
SCALE
km 1
0
1 km

If a central water supply was constructed to serve the domestic needs of the entire community, the system would have to have sufficient capacity to meet both average daily flow requirements as well as peak demand at any given time. Based on a consumption of 0.27 m^3/day per person, and a population of slightly less than 300 people, it is likely that a supply of approximately 82 m^3/day (0.94 L/sec.) would meet the average daily requirements of the community. To meet peak demand approximately 3 times this rate (2.8 L/sec.) would probably be required.

It is clear from the pump test data that the average daily flow requirements for the community could be met by the two test wells, but together they might have difficulty meeting the peak demand of 2.84 L/sec. Furthermore with just these two wells there would be no provision for back up water supply at times of peak demand, in the event of mechanical failure, or other interruption of supply from either well. In the event that a central water supply was developed, it is likely that the construction of a third well in the same area as the two test wells would be sufficient to ensure an adequate supply for the community. As noted earlier it would be advisable to locate the third well further back from the road (perhaps near the edge of the field near the woods) to minimize the likelihood of contamination of the well.

When considering the establishment of any sizable water supply, it is important to consider the impact of groundwater withdrawals on other water users, including potential effects pumping may have on surface water flows in the area. The concern over impacts on surface water flows stems from the fact that a very significant portion of stream flow in P.E.I. is from baseflow (groundwater discharge into streams). A significant reduction in the amount of groundwater available could seriously reduce stream flows in the dryer months of the year. In the case of Miminegash, the volume of water which would be pumped is so low that no such impacts would be anticipated. Pump test data would suggest that interference effects between any adjacent wells should be minimal if detectable. In terms of impacts on surface water resources, the nearest permanent fresh water stream is situated in a sub-watershed (see Figure 6) with an area of approximately 8.5 Km^2. Assuming that annual precipitation is in the range of 1100 mm per year, and that annual recharge averages 35% of precipitation, then the expected water requirements of the community would represent less than 0.01% of the available recharge to the stream.

6.2 Groundwater Protection Strategies

The importance of groundwater resources to the health and welfare of Island communities is well recognized. To a lesser extent the importance of implementing sound, far sighted strategies aimed at protecting this resource is also appreciated. The following discussion attempts to provide some focus to this issue, by presenting some possible approaches to the

protection of groundwater resources. The issue of groundwater protection can be divided into two components: specific recommendations for the protection of central water supply wells and general considerations pertinent to protection of the groundwater resource as a whole.

It is worth noting at the outset, that steps taken toward groundwater protection are worthwhile whether or not a community is contemplating the establishment of central water supply service in the near future or not. Even in the event that no such system is planned, by identifying the available groundwater resources, and implementing measures to protect this resource, these steps will help ensure their availability for future use.

Well Field Protection

Unlike the processes that lead to the contamination of surface water bodies, the degradation of groundwater resources is not subject to direct observation, and consequently is more difficult to predict or correct. Once contaminants have been introduced into a groundwater system, their migration and fate is governed by a complex series of reactions and processes which depend on a number of parameters which may be only poorly documented. Consequently the prediction of the consequences of the introduction of contaminants into a groundwater reservoir in the vicinity of wells supplying a water supply system requires a number of approximations and assumptions of varying validity.

A number of approaches have been developed to provide varying degrees of protection to water supply wells. In general the object of these strategies is to designate an area around the well or well field in which activities which have the potential to have an adverse effect on the water supply are prohibited or restricted. Frequently, a number of concentric zones around a well or well field are defined, with progressively less restrictive land use restrictions for areas further from the well or wells.

The major parameters in developing Groundwater protection strategies for municipal wells are legal , socio - economic, and hydrogeological (Alan Gregory, 1988). In this report, suggested protective strategies are based primarily on hydrogeological parameters. It is recognized that the modification of these strategies in the light of socio - economic factors may be necessary, however the principles behind them do provide a defensible, technical basis for decision making regarding the protection of groundwater resources.

There are a variety of techniques which have been employed to define the extent of various groundwater protection zones. Three types of zones considered in this report are defined below.

Radius of Influence - The areal extent of the cone shaped depression of the water table or pieziometric surface, resulting from the pumping of water from a well or well field. Within this area it is recommended that no residential , commercial or industrial development takes place, and that restrictions be placed on agricultural activities. The area would however be suitable for the development of some types of recreational activities.

Delay Time Zone - Given information direction and magnitude of the hydraulic gradient and the aquifer characteristics, it is possible to estimate the velocity of groundwater or a contaminant towards a well under pumping conditions. The 60 day delay time zone represents the area within which a potential contaminant could migrate to the well within a 60 day period.

It is recommended that within this area, on-site sewage disposal (septic systems), and the storage or handling of hazardous materials (including petroleum product be prohibited. In addition any development proposals or activities should be subjected to an environmental impact assessment, at least in regard to their potential impact on the integrity of the water supply system.

Catchment Area - A zone outlining the area in which groundwater is expected to flow to the well or well field, both under pumping conditions and under the existing natural hydrogeological flow regime. Within these areas, major development proposals or proposed land use changes should first be subjected to an environmental impact assessment.

Each of these approaches has its strengths and weaknesses, and it is perhaps advisable to develop well field protection measures which incorporate aspects of each approach. A set of well field protection zones for the two test wells constructed as part of this program is outlined below, based data from the test drilling and pump testing activities.

Radius of Influence:

When water is being pumped from a well, the water table (or pieziometric surface) in the surrounding area is depressed, creating a change (increase) in the hydraulic gradient towards the well. This cone shaped depression is commonly referred to as the "cone of depression" or the "radius of influence of the well".

Various techniques can be employed to estimate the extent of this area, which will depend on the duration and rate of pumping, aquifer characteristics, and other hydrogeological parameters. Some of these parameters exhibit temporal variability (eg. recharge to the aquifer) while other factors may exhibit spatial variability (eg. hydraulic conductivity of the aquifer), thus certain simplifying assumptions usually must be made, in order to determine the extent of this zone.

It is assumed here for instance, that all pumping from the well or wells is at a constant rate for a duration of 180 days without any recharge to the aquifer. Furthermore, aquifer parameters such as hydraulic conductivity and storativity are assumed to be uniform over the area , and are reasonably represented by values form the available pump test data.

Because from a theoretical standpoint, the areal extent of the cone of depression may be infinite, some practical boundary must be assumed. For the purposes of this study, this boundary is drawn at the point where the hydraulic gradient induced by pumping is equal to, or less than the natural hydraulic gradient (ie. at a distance at which it is difficult to distinguish the effects of pumping on the natural hydraulic gradient.

Based on the these assumptions the radius of influence for test well MIM-1 and MIM-2 have been calculated. For test well MIM-1 pumping at a rate of 0.75 L/sec., the radius of influence extends in a downhill direction (to the south west) approximately 30 m and in an uphill direction approximately 75 m. For test well MIM-2, pumping at a rate of 1.8 L/sec the radius of influence is expected to extend down hill approximately 75 m and uphill approximately 150 m.

Delay Time Zone:

The rate at which contaminants can travel towards a well is a function of a number of factors , including the nature of the aquifer materials, the natural hydraulic gradient and the hydraulic gradient induced by pumping. As might be expected the higher the pumping rate the more rapidly a contaminant could migrate towards the well. A 60 day delay time zone should provide protection from most pathogenic organisms (60 days is the maximum time most pathogens area believed to survive in groundwater), and could also provide a sufficient amount of time in which to find an alternative well location if a particularly serious incident of contamination threatened the water supply.

Thus for instance a spill of a hazardous material occurred at the boundary of this zone, the community would have approximately 60 days before the contaminant was expected to reach the well. It should be noted that many contaminants will travel more slowly than groundwater , thus an extra measure of safety is included in this value.

For test well MIM-1 it is predicted that the 60 day delay time zone extends approximately 100 m in an uphill direction and about 60 m in the downhill direction. For test well MIM-2, the uphill extent of the zone extends approximately 160 m in an uphill direction and 60 m in a down hill direction.

The extent of these two zones are shown of figure Figure 7. A single boundary is shown for each zone as the combined influence of the two wells has been shown rather than the effect of each well individually. As can be seen the radius of influence and the 60 day delay time zone more or less over lap. This is primarily because of the relatively low hydraulic conductivity of the aquifer which contributes to rather slow migration of water through the aquifer.

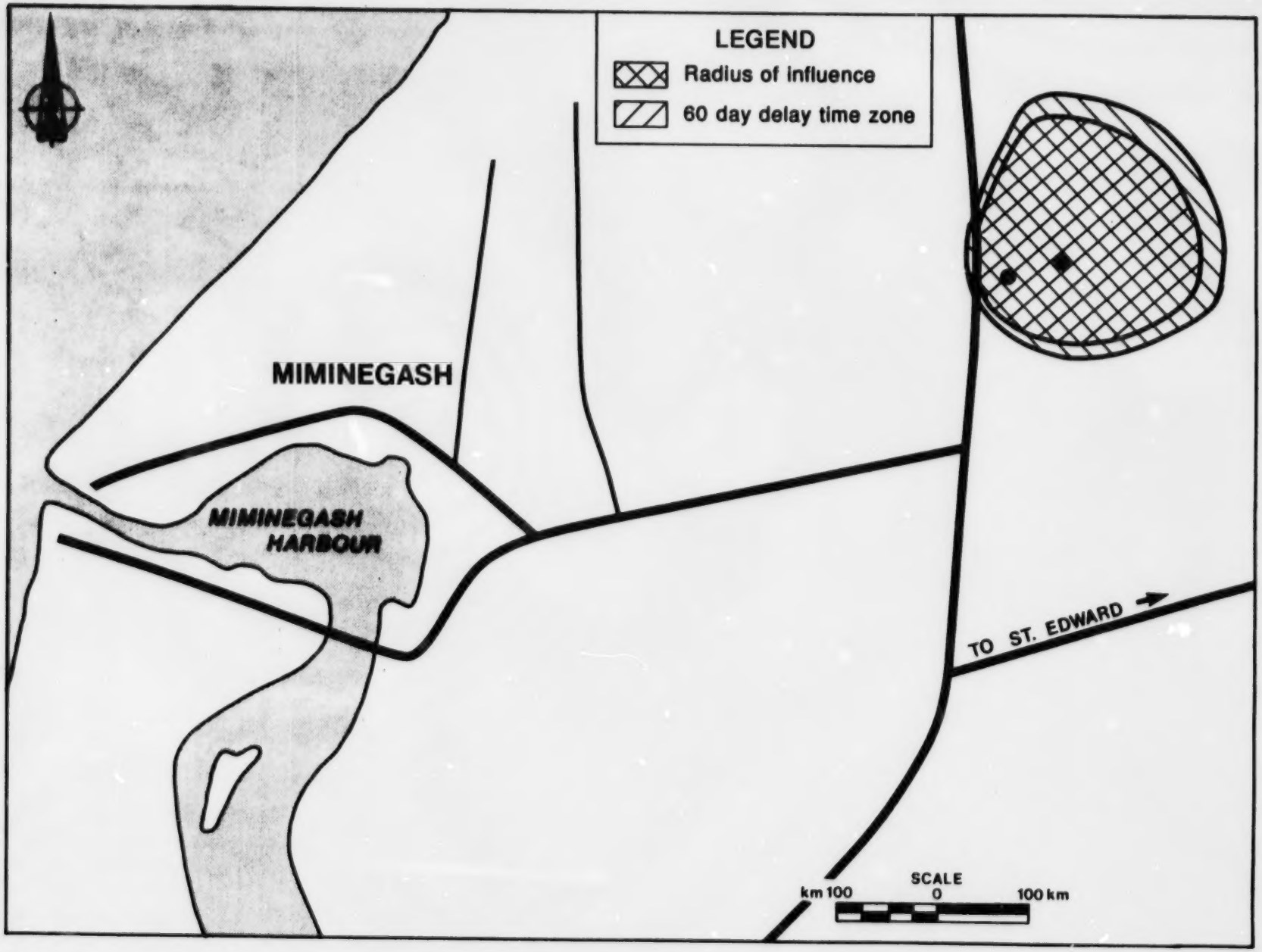

LEGEND
Radius of influence
60 day delay time zone
MIMINEGASH
MIMINEGASH HARBOUR
TO ST. EDWARD
SCALE
km 100
0
100 km

Figure 7

Similarly, the recharge area for the wells is also expected coincide with these zones, as they reach as far up-slope as the nearest topographic divide. For convenience therefore it is probable that a single well field protection zone would adequately address all three approaches to groundwater protection in this area.

General considerations for the protection of groundwater.

It is more difficult to develop comprehensive guidelines to help ensure the overall quality of groundwater in a region as a whole. As well, many of the more general aspects of groundwater protection are covered by acts or regulations of various levels of government. A few areas that can be addressed are outlined below.

As has already been noted natural groundwater quality in the Miminegash area varies considerably both from place to place and at different depths. Beyond these naturally imposed limitations, it is possible to minimize the risk of poor water quality by ensuring adequate well construction procedures. Ensuring that adequate lengths of casing, properly sealed in the ground and with the top of the casing either left above ground level (and properly capped) or enclosed in a properly constructed water tight well pit, can minimize the chances of bacterial contamination.

Proper construction and maintenance of septic systems can also help to reduce the incidence of bacterial contamination, especially in areas of high water tables or particularly tight (l permeability) soils. Similarly, the density of housing (ie lot sizes) should be considered with relation to soil characteristics, ensuring adequate room for proper treatment of sewage without interference with nearby water supplies.

In addition, in areas where the ground is low lying or swampy and iron and manganese are known to be a problem, casing off the more shallow water occurrences may improve water quality. Caution must be exercised in coastal areas however, and it may be more desirable to drill relatively shallow wells were salt water intrusion is likely.

Another step which could reduce the general degradation of water quality in the area, is to ensure that wells that are no longer in use are properly abandoned. This particularly important for wells which have been abandoned due to poor water quality, as the wells could be a potential conduit, allowing the migration of poor quality water from contaminated parts of the aquifer to other portions which were previously un-contaminated. Thus for instance contaminated near surface water entering a well with inadequate casing could migrate down the well bore, and into deeper portions of the aquifer, and into other wells. Conversely, a deep well which encounters salt water at depth may provide a path way for this undesirable water, into shallower fresh water portions of the aquifer.

7. Conclusions and Recommendations

The geology, topography, and proximity to ocean are the main factors determining the quantity and quality of ground water in the Miminegash area. The relatively low permeability of aquifer materials in the region results in fairly low well yields relative to some other areas of the Island, as well as rather sluggish groundwater movement, at least at depth. Groundwater quality varies considerably, reflecting the effects of sea water in near shore areas and the influence of both shallow, local flow systems and a more extensive regional flow system.

Except for instances of saltwater intrusion, natural water quality is acceptable, although frequent high manganese concentrations and to a lesser extent iron concentrations cause aesthetic concerns. The high sodium content of water from the deeper regional flow system could potentially be of concern to people on a low sodium diet.

With the exception of a single petroleum spill at the service station, and the occasional incidence of bacterial contamination of well water, manmade activities do not appear to have caused particularly serious degradation of groundwater quality in the community. Nonetheless, it is a regrettable fact of life, that water quality overtime will continue to degrade as a result of the accumulated effect of man's activities.

In light of the current limitations in obtaining suitable water supplies in the Miminegash area, it would be wise for the community to consider ways of maximizing the benefits from the existing groundwater resources, and to look at ways for preserving the resource for the future.

Whether or not this planning involves the establishment of a central water supply, with appropriate well field protective measures or not, steps should be taken to protect, perhaps through some form of land use restrictions, an area which could provide the necessary quantity and quality of water for future use.

Towards this end, the site of the test drilling, conducted as part of this study, could be an appropriate place to start. Other suitable sites might also be available, depending in part on future development trends in the community, land ownership questions and the size of the area required to provide adequate protection for the source of supply, and of course the availability of funds for water supply development, which will have an impact on the distance the source of supply will be from the centre of the area to be serviced.

Other less direct ways in protecting groundwater resources, particularly if the community continues to rely on on-site water supplies include ensuring proper operation of on - site sewage disposal and lot sizes sufficient to accommodate these systems, adequate well construction standards, proper abandonment of wells, and prevention of spills of hazardous materials.

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APPENDIX I

WATER WELL DATA

APPENDIX I
MIMINEGASH

WATER WELL DATA

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
Fisheries & Oceans	850310	406880	5192200	100	5	20	84	10	5	0–44 Sand and organic silt	83 88
										44–100 Sandstone, some claystone	
Dept. of Fisheries	790618	406800	5192200	75	10	5	48	4	20	0–23 Sand till	70 72
										23–75 Claystone, some sandstone	
Dept. of Fisheries	780529	406006	5192200	158	10	7	43	4	12	0–40 Sand till	57 58 80 81
										40–158 Claystone and siltstone	
Dept. of Fisheries (still water at 40')	780520	406020	5192200	110	10	5	46	4	10	0–20 Sand till	95 96
										20–110 Claystone, some sandstone	
Earl Murphy	780930	406100	5192100	82	45	36	44	10	5	0–15 Till	65 68 85 88
										15–82 Claystone, some sandstone	
Dougie's Fisheries	790615	406100	5192300	75	80	40	55	0	5	0–40 Sand	57 60 72 75
										40–75 Claystone and sandstone	
Miminegash Ice Club	880615	406100	5192400	70	80	20	55			0–55 Sand and claystone, mud	60 63 66 70
										55–70 Claystone	
Judith Dougie	880723	406106	5192400	166		40	40			0–10 Claystone and sand	80 83 100 103
										10–166 Sandstone, some claystone	
Charles Daigle	770419	406200	5192400	80	5	12	35	6	15	0–25 Sand	40 42 52 55
										25–80 Claystone and sandstone	
Elizabeth Gallant	780803	406200	5192500	62	5	15	49	5	10	0–47 Sand till, some clay	55 58 74 77
										47–62 Claystone and siltstone	
Betty Gallant (salty water)	830523	406200	5192900	60	50	15	48			0–48 Muddy sand	59 60
										48–60 Sandstone and claystone	
Betty Gallant (salty water)	830523	406200	5192800	60	25	10	48			0–3 Sand and clay	51 54 59 60
										3–60 Sandstone and claystone	
Fisheries & Oceans	840218	406300	5192000	200		8				0–22 Sand till and clay	
										22–200 Claystone, some sandstone, siltstone	
Fisheries & Oceans	840217	406300	5192020	100	10					0–19 Sand till and clay	
										19–200 Sandstone and claystone, some siltstone	
Mrs. Agnes Gallant	700901	406300	5192100	84	25	10	18	6	15	0–18 Clay and sand	29 31 59 62
										18–84 Claystone and sandstone	
Wilfred Daigle	770418	406300	5192300	115	15	40	69	6	15	0–27 Sand and clay till	85 87 108 110
										27–115 Claystone and siltstone	
Carl Thibideau	770420	406300	5192500	55	10	8	55	6	15	0–20 Sand	37 40 48 50

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. (ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)
										20–55 Claystone and sandstone	
Greta Thibodeau	770515	406300	5182550	63	25	12	51	3	10	0–36 Sand	50 60
										36–63 Claystone, some sandstone	
Myrl Deagle (salty water)	830622	406300	5182500	55	25	15	40			0–3 Clay and sand	
										3–55 Claystone	
Jane Tremblay	831206	406400	5182300	120	50	20	57			0–2 Clay	
										2–120 Claystone and sandstone	
Cara Doucette	750207	406400	5182500	90	50	24	42	5	10	0–11 Clay till	75 85
										11–90 Sandstone and claystone	
Andrew Gallant	711111	406402	5182483	75	10	13	28	5	15	0–6 Sand	42 46 72 75
										6–75 Claystone, sandstone and siltstone	
Leo Ellsworth	721001	406403	5182583	47	15	15	21	3	60		23 25
Louis Doucette	700804	406450	5182460	55	25	25	33	5	15	0–20 Sand	45 48 50 53
										20–55 Claystone and sandstone	
Roger Carragher	850515	406500	5182200	55	50	35	41			0–20 Sand and claystone	20 35 52 55
										20–55 Sandstone and claystone	
Freeman Gallant	770901	406500	5182300	115	10	20	55	5	10	0–9 Sand till	75 85 105 115
										9–115 Claystone and sandstone	
Everett Wedge	790414	406500	5182700	55	50	40	50	5	15	0–4 Clay	50 53 54 56
										4–55 Sandstone and claystone	
Everett Costain	700810	406550	5183000	80	15	15	12	5	10	0–7 Sand	30 33 55 58
										7–80 Claystone and sandstone	
George Gautier (signs of contamination)	700715	406552	5182484	90	25	27	25	2	5	0–15 Sand till	60 65
										15–90 Claystone and sandstone	
James Deagle	810630	406700	5182400	70	25	30	50	5	5	0–3 Till	55 65 69 70
										3–70 Claystone and sandstone	
Ernest Hedge	790609	406700	5182900	82	50	1	33	5	10	0–2 Clay	51 54 75 77
										2–82 Claystone and sandstone	
Patrick Deagle	700901	406800	5182480	58	25	15	21	5	15	0–15 Sand and gravel	27 30 51 54
										15–58 Sandstone	
Mississagash Fire Hall	720515	406803	5182282	164	7	27	26	20	15	0–14 Sand	60 65 90 100 120 155
										14–164 Claystone and sandstone	
Carl Doucette	771230	406850	5182200	30	25	12	30	10	30	0–25 Till	

Name	Date	East. (m)	North. (m)	Depth (ft)	G.S. Elev. -(ft)	S.W.L. (ft)	Casing Length (ft)	Yield (igpm)	Time (min)	Geology	Aquifers (Water Occurrences)			
										25–50 Sandstone and claystone				
Gaudet	720620	468000	5182300	67	10	35	42	6	10	0–6 Sand till	55	58	60	63
										6–67 Sandstone and claystone				
Joseph Gallant	616800	468000	5180000	132	80	48	30	5	10	0–0 Clay	80	93	130	132
										0–132 Claystone and sandstone				
Dale Gallant	800620	467100	5182300	100	50	30	31	5	10	0–55 Sand and claystone	65	68	90	100
										55–100 Sandstone and claystone				
Augustine Hustler	770624	467200	5182300	144	90	52	57	7	10	0–10 Clay till	85	75	130	140
										10–144 Claystone, some sandstone				
John Mills	700015	467301	5182193	60	25	30	27	5	6	0–26 Clay till	41	57		
										26–60 Claystone				
Wayne Gallant	790621	467468	5182500	120	80	34	26	5	7	0–25 Till	54	97		
										25–120 Claystone				
Aldena Butler	711116	467481	5182184	102	25	42	42	5	10	0–6 Clay till	52	86	96	99
										6–102 Claystone and sandstone				
Gary Gaudet	790801	467500	5182200	66	50	55	20	5	10	0–20 Sand and claystone	41	44	67	66
										20–66 Sandstone and claystone				
Herb Thibideau	791210	467600	5182300	110	25	35	42	5	10	0–14 Sand till	80	90	105	110
										14–110 Sandstone and claystone				
Joseph Perry	790814	467700	5182300	80	25	20	25	5	10	0–15 Clay till, some sand	32	35	49	60
										15–80 Sandstone to claystone				
Edward Butler	791035	467700	5183700	75	25	40	25	5	7	0–3 Clay	60	63	73	75
										3–75 Sandstone and claystone				
Eric Perry	790908	467800	5182700	45	50	30	25	5	5	0–27 Sand and claystone	31	34	39	40
										27–40 Sandstone				
Wayne Gaudet	791012	467900	5182300	50	25	40	25	5	5	0–24 Sand and claystone	36	41	45	46
										24–50 Sandstone and claystone				
Mark Boutet	830706	467900	5182300	50	50	15	30			0–1 Clay				
										1–50 Claystone and sandstone				
			Averages	80		34	30	6						

APPENDIX II

WATER QUALITY DATA

APPENDIX II
Water Quality Analyses
MIMINEGASH

Name	Date	Easting/Northing	Parameters																
			Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	pH	Fe (T)	Fe (D)	Mn	Cu	Pb	Zn
Joseph Butler	760729	406300/5192240	250.0	25.50	190.0	6.20	550.0	237	477				7.1	0.0	<0.1	0.10			
Patricia Butler	830609	405150/5192480	24.1	3.78	378.0	5.30	80.0	295	360	28	0.04	<0.2	8.3	<0.1	<0.1	0.03	0.02	<0.1	0.46
William Butler	760728	406600/5192340	109.0	14.80	24.5	3.90	365.0	223	90				7.8	0.0	<0.1	0.20			
William Butler	830127	406690/5192340	7.2	0.67	118.0	2.40	21.7	188	27		0.08	0.7	8.6	<0.1	<0.1	<0.02	0.03	<0.1	0.53
H. Callaghan	830127	406600/5191800	8.9	1.05	99.0	2.90			28	14	0.04	3.1	8.7	<0.1	<0.1	<0.02	<0.02	<0.1	0.15
W. Callaghan	821118	406600/5191700	94.0	44.90	187.0	185			55	40	0.06	0.2	8.5	0.1	<0.1	1.02	0.02	<0.1	0.04
W. Callaghan	830127	406600/5191700	9.9	0.68	183.0	1.50			50	90	0.05	0.9	8.6	<0.1	<0.1	<0.02	<0.02	<0.1	0.28
Dell's Canteen	760519	406100/5192140					38.0		98			2.2	8.4	0.8					
Dell's Canteen	760908	406100/5192140	187.0	30.00	280.0	5.30		191	900		0.06	<0.2	7.6		<0.1	0.35	<0.02	<0.1	0.05
Alton Carragher	760728	406630/5192260	105.0	22.00	20.5	5.00	336.0	227	58			1.0	7.8	0.0	<0.1	0.50			
John Carragher	760728	406690/5192270	113.0	18.50	25.0	3.70	381.0	243	70			1.5	7.8	0.0	<0.1	0.35			
Everett Costain	810903	406600/5192300	128.0	5.80	33.0	4.00	344.0	204	80	12	0.16	<0.2	8.3	0.5	<0.1	0.85		<0.1	0.76
Benny Deagle	760601	406400/5192300	81.0	15.00	26.0	8.00		210	70			1.5			<0.1	0.70			
Benny Deagle	821028	406400/5192300	110.0	17.25	29.5	11.10			130	19	0.10	<0.2	8.2	0.2	<0.1	0.94	0.10	<0.1	0.44
Charles Deagle	760728	406340/5192320	155.0	16.00	33.5	4.00	338.0	294	110			2.7	7.5	0.2	<0.1	0.50			
James Deagle	760728	406700/5192400	75.0	12.00	24.5	4.00	288.0	195	68			1.0	7.8	0.0	<0.1	0.05			
Jimmy Deagle	811119	406800/5192300	24.0	3.00	130.0	4.00	73.0	194	60	14	0.10	<0.2	8.2	0.2	<0.1	0.10	0.02	<0.1	0.10
Leo Deagle	760728	406850/5192400	2.0	0.40	130.0	1.70		173	33			8.0	8.6		<0.1	<0.02			
Myrl Deagle	760728	406400/5192280	85.0	17.20	26.0	8.00	340.0	202	67			1.0	7.4		<0.1	0.30			
Patrick Deagle	760729	406800/5192500	24.0	7.00	23.5	5.70	136.0	106	33			5.9	7.0	0.0	<0.1	0.05			
Patrick Deagle	870618	406800/5192500	88.0	12.18	62.0	5.10	275.5	264	65		0.04	<0.2	7.5	<0.1	<0.1	2.39	0.04	<0.1	0.74
Wilfred Deagle	760623	406420/5192300	255.0	6.50	62.0	3.00	*****	446	300			5.0	7.1	0.1	<0.1	1.00			
Edwin Doucette	760728	406400/5192500	65.0	16.50	150.0	9.00	280.0	263	188			1.8	7.9	0.0	<0.1	1.00			
Louis Doucette	760601	406450/5192450	20.0	5.50	150.0	4.00		220	65			<0.2			<0.1	0.10			
John Ellsworth	770512	406450/5192600					424.0		92			1.8	6.8	2.0					
John Ellsworth	760602	406450/5192600	117.0	9.00	29.0	1.70		243	70			0.2			<0.1	4.50			
Leith Gorveatt	780529	406030/5192200					24.0		125			7.5	8.4	0.4					
Andrew Gallant	760601	406450/5192500	52.0	10.50	50.0	5.50		189	48			<0.2			<0.1	0.85			
Mrs. A. Gallant	760602	406350/5192400	61.0	13.80	37.0	8.00		197	55			5.8			<0.1	0.42			
Mrs. A. Gallant	800811	406350/5192400	50.0	10.00	80.0	7.00		214	65	<5	0.10	<0.2	8.3	0.1	0.1	0.50	<0.02	<0.1	0.20
Alfred Gallant	760602	406450/5192400	33.0	8.50	40.0	5.60		147	28			3.4			<0.1	0.18			
Alfred Gallant	760605	406450/5192400	38.0	9.00	36.0	0.20		150	28		0.08	<0.2	7.4		<0.1	0.23	<0.02	<0.1	0.05

Name	Date	Easting/Northing	Ca	Mg	Na	K	Hard.	Alk.	Cl	SO4	P	NO3	pH	Fe (T)	Fe (D)	Mn	Cu	Pb	Zn
Betty Gallant	781025	406300/5192550	105.0	29.50	640.0	14.00	366.0	440	950		0.15	1.8	7.4	6.8	< 0.1	0.95	0.08	< 0.1	0.10
Betty Gallant	830609	406300/5192550	102.6	24.90	*****	24.70	490.0	456	> 9999	8	0.04	< 0.2	8.0	0.4	< 0.1	0.77	0.04	< 0.1	0.08
Mrs. E. Gallant	760728	406300/5192280	145.0	10.50	37.0	2.00	314.0	277	120			2.2	7.6	0.2	< 0.1	3.00			
Edward Gallant			16.0	5.50	47.0	5.20		130	25						< 0.1	0.02			
John Gallant	760906	406470/5192200	210.0	21.70	90.0	2.30		416	180		0.10	< 0.2	7.4		< 0.1	1.30	< 0.02	< 0.1	0.20
Melvin Gallant	820826	406600/5192700	37.8	6.16	40.0	3.70		246	25	5	0.10	< 0.2	7.2	0.3	< 0.1	0.11	< 0.02	< 0.1	0.53
Rita Gallant	760728	406850/5192340	2.7	5.10	132.0	2.20	35.0	181	37			12.1	8.5	0.2	< 0.1	< 0.02			
Ronnie Gallant	800412	406500/5192500	48.0	14.00	58.0	6.60	176.0	214	10	10	0.10	< 0.2	8.2	0.1	< 0.1	0.55	0.05	< 0.1	0.21
Ronnie Gallant	840717	406500/5192500	72.3	13.95	79.0	7.60	239.5	236	140		0.05	< 0.2	8.0	< 0.1	< 0.1	0.53	< 0.02	< 0.1	0.25
Ronnie Gallant	850723	406500/5192500	84.8	16.87	62.0	8.70	282.8	247	80		0.10	< 0.2	7.4	0.2	< 0.1	0.62	0.12	< 0.1	0.20
Wayne Gallant	760729	406950/5192180	2.4	5.10	148.0	2.10	50.0	234	20			1.3	8.4	0.1	< 0.1	0.02			
George Gaudet	760729	406400/5192500	91.0	7.50	52.0	4.00	450.0	328	25			1.3	6.9	0.6	< 0.1	3.00			
Isedore Gaudet	760728	406850/5192350	9.5	2.05	89.0	4.20	54.0	157	67			12.7	8.1	0.0	< 0.1	< 0.02			
Genu Products	760728	406050/5192500	170.0	*****	*****	*****	950.0	613	2380			2.0	7.8	0.8	< 0.1	1.00			
Mildred Hustler	760602	406450/5192400	84.0	13.00	22.0	7.00		171	50			3.2			< 0.1	0.27			
Irving S.S.	760809	406780/5192370	73.0	10.00	45.0	5.40		172	58		0.06	5.8	7.7		< 0.1	0.02	< 0.02	< 0.1	0.20
John Jones	810402	407100/5192200	10.0	0.80	140.0	1.05		215	17	9	0.14	0.2	8.3	0.1	< 0.1	0.02	0.02	< 0.1	0.20
Laurie Jones	840911	406500/5191600	10.3	2.10	101.1	2.86	34.9	175	31		0.10	0.5	7.7	< 0.1	< 0.1	< 0.02	< 0.02	< 0.1	0.24
Robert Jones	760728	406780/5192200	18.0	6.50	70.0	5.40	73.0	142	23			3.0	8.0	0.0	< 0.1	< 0.02			
Howard McCorma	760728	406750/5192250	21.0	6.70	55.0	6.20	140.0	133	41			3.6	7.8	0.0	< 0.1	0.06			
Marine Plants	760728	406250/5192100	16.0	3.50	170.0	3.80	66.0	207	77			1.1	8.1	0.0	< 0.1	0.03			
Deagle Fish.		406100/5192300	78.0	17.35	565.0	7.60		254	243	41	0.06	< 0.2	8.0	0.5	< 0.1	0.22	0.05	< 0.1	0.84
Fire Hall	760623	406800/5192300	10.0	2.50	94.0	2.80	83.0	174	26			4.4	8.5	0.2	< 0.1	< 0.02			
Mrs. P. Murphy	760809	406400/5192200	39.0	9.90	58.0	13.00		187	25		0.06	0.7	8.3		< 0.1	< 0.02	< 0.02	< 0.1	0.05
Raymond Murphy	760728	406320/5192200	50.0	11.50	34.0	7.00	242.0	161	50			1.8	7.9	0.0	< 0.1	0.06			
Strait water	760728	406200/5192700	175.0	*****	*****	*****		72	25000						< 0.1	0.05			
Wendell Stewart	760728	406100/5192200	5.0	1.10	200.0	2.70	40.0	212	78			1.0	8.6	0.1	< 0.1	< 0.02			
Carl Thibodeau	780830	406300/5192500					418.0		424			2.2	7.4	1.9					
Carl Thibodeau	800811	406300/5192500	54.0	11.60	110.0	6.90		252	130	< 5	0.06	< 0.2	8.2	0.1	< 0.1	0.90	< 0.02	< 0.1	0.07
Daly Thibodeau	760602	406500/5192350	67.0	14.00	52.0	8.00		203	95			3.6			< 0.1	0.55			
Daly Thibodeau	850730	406500/5192350	44.0	9.96	107.0	5.60	152.6	233	140		0.12	< 0.2	7.6	< 0.1	< 0.1	0.59	< 0.02	< 0.1	0.33
Fred Thibodeau	760623	406600/5192320	165.0	14.60	46.0	1.35	473.0	360	31			1.8	7.3	0.1	< 0.1	2.50			
Gerald Tremblay	760728	406600/5192250	140.0	14.20	35.0	2.65		342	100						< 0.1	0.85			
Jane Tremblay	840724	406400/5192300	74.5	11.38	84.0	7.10	235.7	279	100		0.09	0.5	7.2	< 0.1	< 0.1	1.25	0.04	< 0.1	0.27
Mrs. J. Tremblay	760623	406600/5192250	17.0	4.30	105.0	3.75	64.0	187	37			1.3	8.1	0.5	< 0.1	0.06			
Mrs. J. Tremblay	760728	406600/5192250	11.0	3.00	170.0	3.85	58.0	218	40			1.0	8.4	0.1	< 0.1	< 0.02			
Wilfred Tremblay	760728	406450/5192300	270.0	33.50	66.0	2.30	680.0	442	50			2.0	7.5	0.1	< 0.1	1.40			

Emmett Wedge	760728	406750/5192100	12.0	3.40	80.0	4.40	54.0	149	21			2.2	8.5	0.0	< 0.1	< 0.02				
Joe Wedge	760601	406450/5192450	125.0	14.70	57.0	4.30		480	95			< 0.2			< 0.1	0.77				
Margaret Wedge	760629	406500/5192320	155.0	15.50	61.0	1.80	565.0	424	15			1.3	7.0	1.0	< 0.1	3.50				
William Wedge	760728	406600/5192330	125.0	18.50	75.0	3.60	438.0	269	114			5.4	7.4	0.0	< 0.1	0.05				
Fish & Oceans	760629	406300/5192100	48.0	12.00	170.0	5.70	185.0	197	173			1.0	7.8	0.0	< 0.1	0.10				
Fish & Oceans	840229	406300/5192150	15.5	2.65	35.6	2.06	50.2	100	34		0.04	< 0.2	7.6	< 0.1	< 0.1	< 0.02	0.13	< 0.1	0.22	
Fish & Ocean(1)	860107	406250/5192150	23.0	4.80	124.0	4.20	77.8	187	120		0.05	< 0.2	7.7	< 0.1	< 0.1	0.19	0.07	< 0.1	0.08	
Fish & Ocean(2)	860107	406250/5192150	7.8	1.59	155.0	2.00	26.7	205	100		0.04	< 0.2	8.0	0.2	< 0.1	0.16	0.14	< 0.1	0.11	
		CDWS							250	500		10.0	6.5–8	0.3		0.05	1.00	0.05	5.00	